National Aeronautics and Space Administration

Glenn Research Center
Cleveland, Ohio

The Light Microscopy Module: An On-Orbit Microscope Planned for the Fluids Integrated Rack on the International Space Station

The Light Microscopy Module (LMM) is planned as a remotely controllable on-orbit microscope subrack facility, allowing flexible scheduling and control of physical science and biological science experiments within the GRC Fluids Integrated Rack (FIR) on the International Space Station.

Within the FIR, an initial complement of four fluid physics experiments will utilize an instrument built around a light microscope. These experiments are the "Constrained Vapor Bubble" experiment (Peter C. Wayner of Rensselaer Polytechnic Institute), the "Physics of Hard Spheres Experiment–2" (Paul M. Chaikin of Princeton University), the "Physics of Colloids in Space–2" experiment (David A. Weitz of Harvard University), and the "Low Volume Fraction Entropically Driven Colloidal Assembly" experiment (Arjun G. Yodh of the University of Pennsylvania). The first experiment investigates heat conductance in microgravity as a function of liquid volume and heat flow rate to determine, in detail, the transport process characteristics in a curved liquid film. The other three experiments investigate various complementary aspects of the nucleation, growth, structure, and properties of colloidal crystals in microgravity and the effects of micromanipulation upon their properties. Key diagnostic capabilities include *video microscopy* to observe sample features including basic structures and dynamics, thin film *interferometry*, *laser tweezers* for colloidal particle manipulation and patterning, *confocal* microscopy to provide enhanced three-dimensional visualization of colloidal crystal structures, and *spectrophotometry* to measure colloidal crystal photonic properties. In addition to using the confocal system, biological experiments can conduct *fluorescence* imaging by using the fiber-coupled output of the Nd:YAG laser operating at 532-nm, the 437-nm line of a mercury arc, or appropriate narrow-band filtering of the FIR provided metal halide white light source.

Key diagnostic capabilities include video microscopy, thin film interferometry, laser tweezers, confocal microscopy, and spectrophotometry.

The LMM concept is a modified commercial research imaging light microscope with powerful laser-diagnostic hardware and interfaces, creating a one-of-a-kind, state-of-the-art microscopic research facility. The microscope will house several different objectives, corresponding to magnifications of 10×, 40×, 50×, 63×, and 100×. Features of the LMM include *high-resolution color video microscopy, brightfield, darkfield, phase contrast, differential interference contrast* (DIC), *spectrophotometry*, and *confocal* microscopy combined in a single configuration. Sample manipulation techniques also integrated with the diagnostics are laser tweezers. The LMM provides an enclosed workarea called the auxiliary fluids container (AFC) with gloveports and an equipment transfer module (ETM) for transporting experiment samples from stowage to the LMM (see figure 1). The multiport imaging head on the top of the microscope provides a motorized slider to select the sensor or sensors to which the images are directed. The AFC is fastened to the microscope body and is sealed to provide a clean working space and one level of containment. Gloveports allow access to the sample area for cleaning before opening the box and experiment sample changeout or reconfiguration. The ETM can be configured to support *various experiment modules* and is located below the AFC which has a pass-through for the samples. Materials are thus transferred without the risk of contamination release. The ETM will be loaded with experiment modules on the ground, and will provide contained storage until the samples are utilized in the experiment.

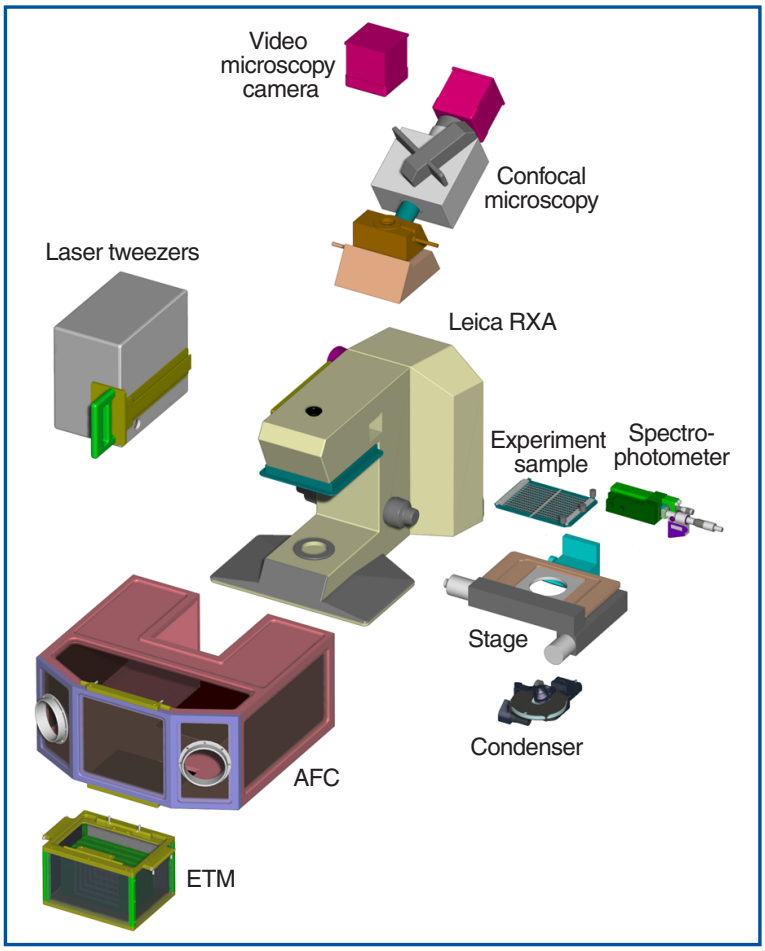

Figure 1. Light Microscopy Module.

Laser tweezers will be implemented using a custom-built system based upon a 1064-nm Nd:YAG laser, beam-focusing optics, and two acousto-optic deflectors to steer the trap within the field of view of the microscope. Laser tweezers simply is the trapping of a colloidal particle using radiation pressure by focusing a laser beam through a high-numerical aperture lens and striking the particle. Figure 2 illustrates a colloidal structure assembled by laser tweezers.

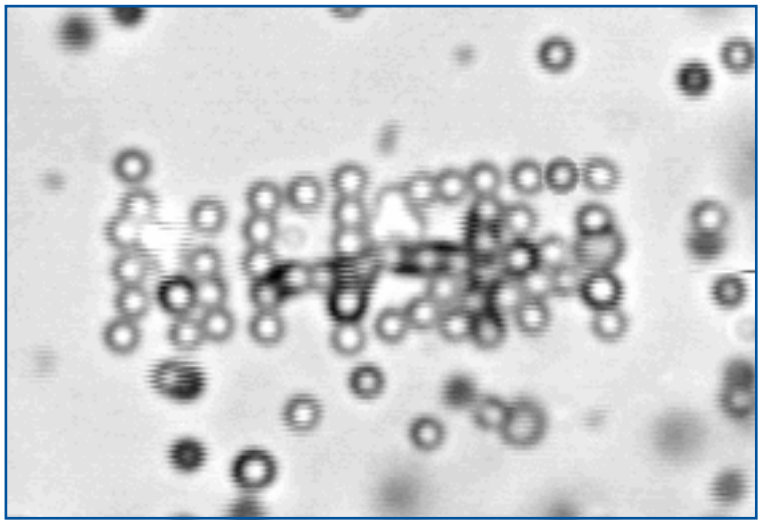

Figure 2. Brightfield image of colloid particles manipulated by laser tweezers.

Laser tweezers will be used to measure the viscosity and viscoelasticity of the fluid. A particle will be trapped and oscillated at a fixed frequency. When this is done, the centroid of the trap and particle will not coincide; the difference in the two positions through the scan provides the driving force. Using that information along with the motion, both linear and nonlinear viscoelastic properties can be computed.

Confocal microscopy will be implemented using a 532-nm frequency-doubled Nd:YAG laser, a confocal scanner, and an 8-bit digital CCD camera. The scanner will allow 30 frames per second of confocal images to the CCD camera. Confocal is used on a fluorescent-dyed sample (figure 3). The crystal's three-dimensional structure is reconstructed by assembling the slices with an image analysis program, from which colloidal growth, structure, and dynamics can be measured (figure 4). The confocal module will be attached and aligned to the side of the LMM and will access the sample through an auxiliary port on the Leica RXA. The microscope's reflected light turret will contain a reflecting mirror to direct the light to and from the sample.

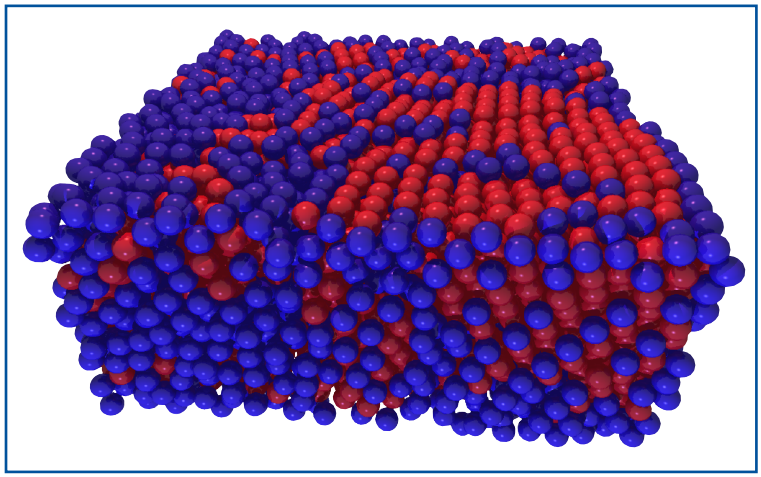

Figure 3. The particles are dyed with rhodamine in order to make them visible for confocal fluorescence microscopy. About 100 image slices are combined to determine the particle positions in a volume.

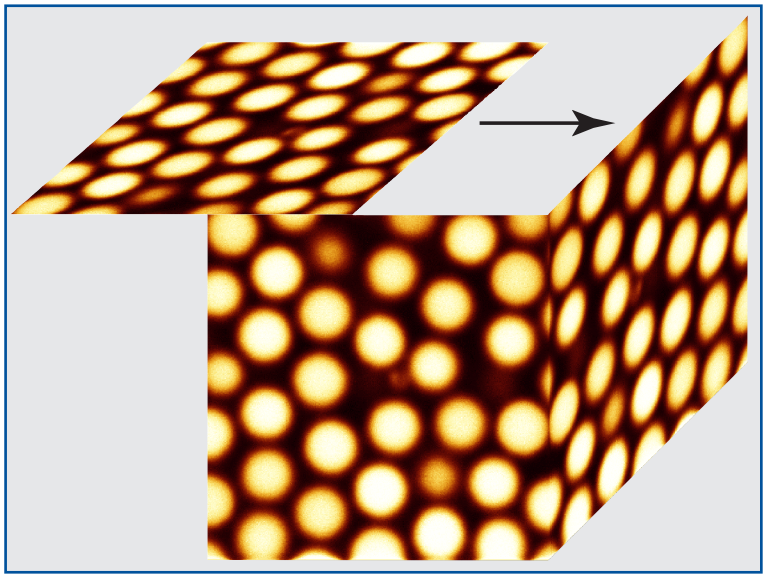

Figure 4. By taking a series of 2-D images as the z-axis is scanned, an "image cube" is built up.

The engineering, design, and development of the LMM is being performed under NASA contract NAS3-99155 (Federal Data Corporation).

For more information visit the

NASA Glenn Microgravity Fluid Physics Web Site at

http://microgravity.grc.nasa.gov/6712/fptp.html

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M–0723–01
Mar 01